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A Meta-Analysis On Driver Safety and Cannabis Impairment

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A Major Qualifying Project Report
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Abstract:

The goal of this project is to determine a procedure to accurately detect an impaired driver influenced by cannabis. Through simulated data constructed from parameters of national cannabis studies, we can measure the accuracy of suggested testing methods for Law Enforcement Officers (LEOs). Eventually, legislation will need to decide on guidelines and laws for LEOs to abide by when identifying drivers under the influence of cannabis, and with our recommendations, Massachusetts legislation will have a meta-analysis to assist with their decisions.

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Introduction:

The use of cannabis has been voted on and made legal in many states in the US for recreational and medical use. Further, Canada has legalized the recreational use of cannabis. With legalization both recreationally and medically becoming more and more prominent in states, progressive cannabis driver safety is needed. At the moment there is no working cannabis breathalyzer or device to regulate drivers who are driving under the influence of cannabis at an illegal and unsafe limit. In order to increase safety and regulate unsafe drivers, research into developing a device or procedure that can accurately gauge whether the driver is driving influenced by Delta-8-THC (tetrahydrocannabinol, the psychoactive chemical in cannabis) at an illegal level is a necessity for law enforcement officers (LEOs).

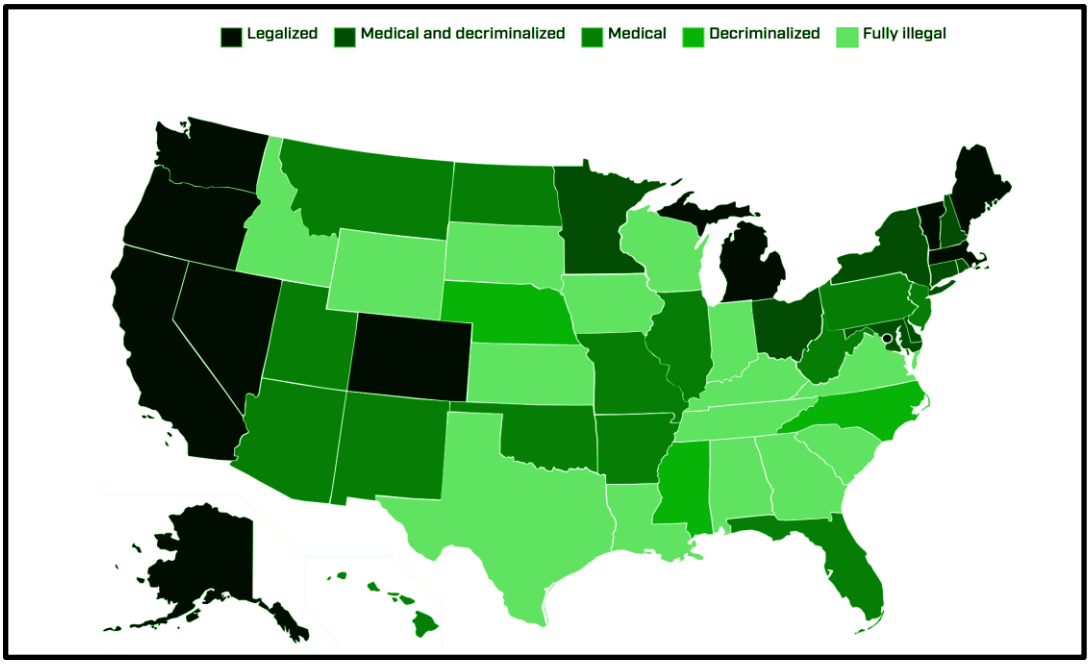

Figure 1. Map as of February 2019 of the United States and which states have decriminalized and legalized cannabis.

Problem Statement:

With the legalization of cannabis across the country, more and more people are driving under the influence of THC posing as a threat to public safety. Unlike alcohol, which can be measured by the blood alcohol content in a person's system via a breathalyzer, cannabis does not have such a device or specific method of confirmation. Therefore, people are driving under the influence of THC unsafely with little-to-no consequence or regulation unless a police officer uses their best judgment or has undergone the Drug Recognition Expert certification. With the help of our MQP, the process of identifying someone who is too "high" to drive will supplement lawmakers when they decide to make a legal limit of consumption.

Project Goals and Objectives:

The goal of this project is developing a test that will accurately determine if somebody is safe or not safe to drive while under the influence of cannabis. In order to do this, the team will have to research and develop ways of determining if somebody is under the influence of cannabis. Once specific signs of cannabis use are determined, the team will then have to create a set of tasks similar to the efficacy of the Standard Field Sobriety Test (SFST) that will test for these key indicators of cannabis use. After the test has been developed, the team would like to create a working mobile application that will expedite the identification of someone being too "high" to drive. After the test is developed, the team will run the test on human subjects to correct and adjust the parameters, developing a workable application will further aid lawmakers to decide where to set a limit of intoxication.

Project Deliverables:

The project deliverable is a cognitive skills test that will evaluate an individual's ability to perform necessary tasks essential to driving under the influence (DUI) of cannabis. The test

consists of five different tasks. Two of the five tasks have been developed into a mechanical prototype using CAD software and physically created.

Along with physical models of our proposed tests there is significant data that can be simulated to go along with our tests. This data will be used to supplement our proposal to legislature when they decided to develop new cannabis driving laws.

Project Scope and its Interdisciplinary and Global Importance:

The team's research and focus will be widespread due to the newness of the cannabis industry. The research and past studies on cannabis will result in an introductory style report that later may be used for further, more targeted research. The global audience of engineers, lawyers, businessmen/businesswomen, and ethical observers will have the opportunity to establish careers and make an impact on this new industry. With new jobs in the cannabis industry alone projected to increase by 250,000 by 2020.[1] Within these new jobs the breath of demographics will be highly specialized careers and part-time opportunities. According to ZipRecruiter, the cannabis industry has already outpaced tech and healthcare industries in most recent years.[1]

The US government has started to take steps towards legalization with the most recent Farm Act, which legalized the growing of Hemp, the non-psychoactive plant in the same plant-family as cannabis.[1] This new legislation allows for the farming industry to revamp and create many products that were once on the brink of innovation before being outlawed in the 1930s for controversial reasons linking this beneficial and non-psychoactive plant with its family member cannabis. It is predicted that the United States' next step will be to remove cannabis from the schedule 1 classification, allowing for further research to be conducted. Along with the US there

[1] Schmults, Edward. "The 2019 Cannabis Industry Forecast." *Money Inc*, Money Inc, 11 Feb. 2019, moneyinc.com/the-2019-cannabis-industry-forecast/.

has been global awareness to the medicinal use of cannabis, looking at figure 2, we can see the global impact cannabis has had in recent times. Most recently, South Korea has begun legalization processes for medical use of cannabis as an alternative medicine. The importance of this new trend will impact people globally, which was one of the reasons our team decided to pursue this project and discover alternative procedures to keep our roads safe from potential impaired drivers.

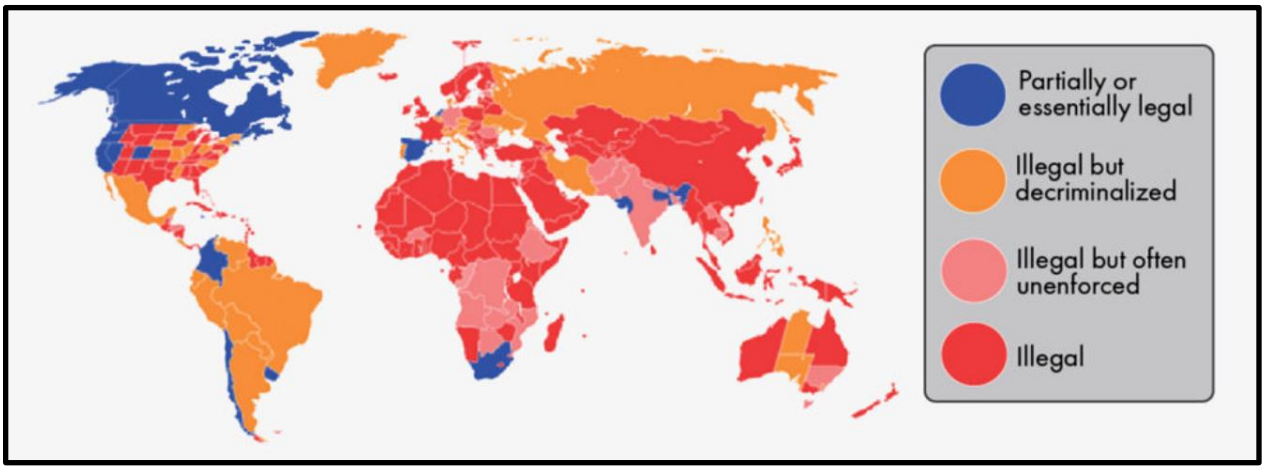

Figure 2: Global snapshot of cannabis legalization[2]

[2] https://www.benzinga.com/markets/cannabis/19/02/13223129/infographic-the-status-of-cannabis-legalization-in-every-state-aroun

Background:

The background chapter will provide a baseline of cannabis knowledge to allow all readers to fully understand the context and importance of this Major Qualifying Project (MQP). As previously mentioned, the cannabis industry as a whole is still in its infancy and with that, there are many precautions our team feels needs to be addressed to a full extent. With a new industry comes many opportunities for engineering students to find ways to get involved with shaping the way the world interprets cannabis not only as medicine but now as a recreational substance that everyone is exposed to in the public scene. This background chapter explains the history of cannabis and how certain parameters of the law will be affected by its legalization. The procedures of current LEOs and the opportunity for innovation are both discussed in the following sections.

Cannabis History:

The United States government has five classifications for drugs, schedule I-V. Schedule V, the lowest, represents a classification of drugs with extremely low risk for abuse. Schedule I represents drugs with a high risk for abuse and no accepted medical use.[3] Cannabis is classified under schedule I at the federal government level.

In the 1800s cannabis was used in the United States in the form of cloth, rope, and paper known as hemp. Hemp remained a popular and cheaper alternative to cotton until the invention of the cotton gin greatly reduced labor and cost in cotton production. Cannabis for medicinal purposes began to be used in the late 1800s. Cannabis did not attract attention in the government until the early 20th century.[4] Starting with California in 1915, states began to outlaw cannabis, however, this failed to stop the popularity of the substance.[5] In 1937, the Federal Bureau of Narcotics was

[3] "Drug Scheduling." *DEA*, www.dea.gov/drug-scheduling.
[4] Burnett, Malik. "How Did Marijuana Become Illegal in the First Place?" *Drug Policy Alliance*
[5] "Marijuana History - America." *Narconon International*, Narconon International

founded, and in 1937 succeeded in passing the Marijuana Tax Act.[6] This act required dealers to pay a tax on the cannabis and enforced many provisions, violations of which could result in prison time. Further tightening of restrictions came in 1952 and 1956. The resulting laws promised a prison sentence of 2-10 years and a fine of up to $20,000 for an individual caught with cannabis. In 1970, Congress repealed the previous two laws, and replaced them with the Controlled Substances Act, officially giving cannabis a schedule I classification.[1]

The first change in attitude towards cannabis came in the early 1970s. President Richard Nixon appointed the Shafer Commission to report on drug abuse. In early 1972, the Commission's Chairman presented a report to Congress that recommended ending the prohibition on cannabis in favor of other tactics to discourage use.[7] As a result of this report, Oregon was the first state to decriminalize cannabis, in 1973.[8] This changed the punishment for cannabis possession from criminal prosecution to a civil penalty more akin to minor traffic violations, in this case, a $100 fine for up to one ounce of cannabis. Following Oregon's example, in 1975, Alaska, California, Colorado, Maine, and Ohio decriminalized cannabis. By 1978, Minnesota, Mississippi, Nebraska, New York, and North Carolina all passed legislation to decriminalize cannabis too.[6]

The first law in favor of using cannabis as a form of medicine passed in California in 1996. Proposition 215, also known as the Medicinal Use of Marijuana Initiative allowed doctors to prescribe cannabis for medical use.[9] Between 1998 and 2011, a further 16 states legalized cannabis

[6] US Legal, Inc. "Marijuana Tax Act Law and Legal Definition." *Fraud Law and Legal Definition*
[7] "Nixon Tapes Reveal Twisted Roots Of Marijuana Prohibition." *Common Sense for Drug Policy: Corruption, An Inevitable By-Product Of The War On Drugs*
[8] Crombie, Noelle. "Legal Marijuana in Oregon: A Look at the State's Pot History." *OregonLive.com,*
[9] "California Proposition 215, the Medical Marijuana Initiative (1996)." *Ballotpedia,* ballotpedia.org/California_Proposition_215,_the_Medical_Marijuana_Initiative_(1996)

for medical use.[10]

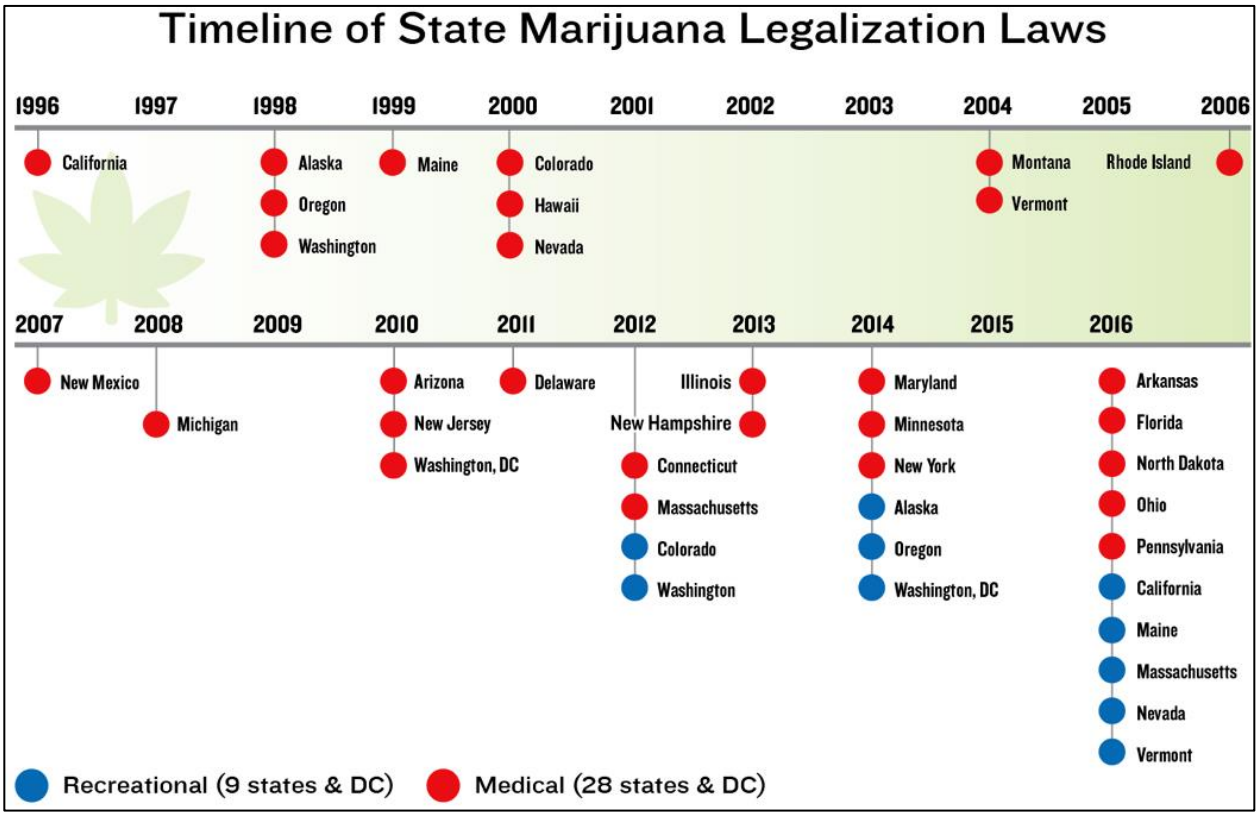

Figure 3: Timeline of State Cannabis Legalization Laws. Note: Since 2016, West Virginia, Indiana, Kansas, Oklahoma, and Michigan have made new legislation towards cannabis.

Medical cannabis has been gaining popularity as an alternative to many medicines, especially pain control. While mostly useless for severe pain, like broken bones or post-surgical pain, it is being used more and more for chronic pain relief.[11] There are two main chemicals known as cannabinoids in cannabis, tetrahydrocannabinol (THC), and cannabidiol (CBD).

Both chemicals serve different purposes and cannabis plants are bred to produce more than one than the other, depending on the purpose of the plant. THC is the more active and popular chemical, which produces the "high" cannabis is known for. It is also known to decrease pain, muscle control problems, nausea, and increase appetite. However, both chemicals have certain

[10] Trumble, Sarah. "Timeline of State Marijuana Legalization Laws – Third Way."
[11] Grinspoon, Peter. "Medical Marijuana." *Harvard Health Blog*, Harvard Health Publishing

medical benefits. CBD is often used for medical purposes like reducing inflammation and controlling epileptic seizures.[12] Another large benefit to medical cannabis is the relatively low addictiveness of it. Many other prescription drugs for chronic pain are opiate-based, which are highly addictive.

The first wave of recreational legalization came in 2012 when Colorado and Washington's voters passed Colorado Amendment 64 and Washington Initiative 502 respectively. These states regulated cannabis in a similar style to alcohol, with adults 21 and older allowed possession of up to an ounce.[13]

At this time, cannabis was, and remains, under a prohibition at the federal level. According to the Controlled Substances Act, there is no difference between medical and recreational cannabis, and it is treated as any other controlled substance, such as cocaine or heroin.[1] However, in 2013, in response to recreational legalization, the Department of Justice published the Cole Memorandum. The Memorandum indicated a shift in government priorities. The primary purpose behind the memorandum is to focus prosecutors and law enforcement on certain priorities, such as preventing distribution to minors, preventing criminal enterprises from gaining revenue from cannabis, preventing authorized cannabis activity from being used as a front for other illegal drugs or activity, and preventing violence surrounding cannabis.[14]

At this point in time, 11 states have legalized recreational cannabis, and a further 22 have legalized medical cannabis. The most recent state to legalize recreational cannabis was Michigan in November of 2018. With more states having ballots voting for legalization there is an increase

[12] "Marijuana and Cannabinoids." *National Center for Complementary and Integrative Health*, U.S. Department of Health and Human Services
[13] Hanson, Karmen, and Alise Garcia. *Affirmative Action | Overview*
[14] Rough, Lisa. "The Cole Memo: What Is It and What Does It Mean?" *Leafly*

in public usage and ultimately a need for more public safety for those first trying the substance or for general safety.

Testing for cannabis specific impairment while operating vehicles is especially difficult to accurately measure. In Massachusetts during 2017, a motorist was charged with operating under the influence of cannabis, in violation of G. L. c. 90, § 24. The officer performed a Field Sobriety Test (FST) on the subject and according to the court ruling "*police officers may not testify to the administration and results of field sobriety tests as they do in operating while under the influence of alcohol prosecutions*," but "*may testify to the administration of 'roadside assessments*;'" that "*lay witness may not offer an opinion that another person is 'high' on marijuana* ("cannabis");" that a "*police officer may testify to observed physical characteristics of the driver such as blood shot eyes, drowsiness, and lack of coordination*," but cannot "*offer an opinion that these characteristics mean that the driver is under the influence of marijuana*("cannabis");" and the jury may "*utilize their common sense*" in deciding if the driver's performance on the roadside assessments indicates his or her ability to operate a motor vehicle safely was impaired.[15] Since not all LEOs of Massachusetts are certified DRE it is obvious of the disconnect between the courts and law enforcement arresting accurately based off their knowledge of cannabis and driving impairment. To help mitigate these concerns, an expedited certification is needed so that all LEOs of Massachusetts, and the whole country, can be aware of the stipulations there to correctly identify and assess driver safety with cannabis.

[15] Doonan SM., Johnson JK., (2019, January). A Baseline Review and Assessment of Cannabis Use and Public Safety Part 1: Operating under the Influence of Cannabis: Literature Review and Preliminary Data in Massachusetts— A Report to the Massachusetts Legislature. Boston, MA:Massachusetts Cannabis Control Commission.

Standard Field Sobriety Test History:

The standard field sobriety test has successfully been applied towards inebriation, but for cannabis-related traffic stops, there is conflicting evidence to back up the effectiveness in determining an individual's capacity to operate motor vehicles.[16] A recent judicial case in Massachusetts, *Commonwealth v. Gerhardt*, 2017, Thomas Gerhardt was pulled over and given an SFST to determine if he was going to be arrested or allowed to proceed to his destination. The case was overruled from the officer's decision because "The scientific community has not reached a consensus as to whether a defendant's performance on any combination of FSTs or any individual FST, is correlated with marijuana use or impairment … Because the effects of marijuana may vary greatly from one individual to another, and those effects are as yet not commonly known, neither a police officer nor a lay witness who has not been qualified as an expert may offer an opinion as to whether a driver was under the influence of marijuana".[17] From this court case, it was discussed how there is a lack of evidence to prove or disprove that an SFST cannot determine the individual's ability to control a vehicle.

Furthermore, a study in 2012 in which case medicinal delta-9 THC, the main psychoactive ingredient of cannabis, was administered to 14 males and 10 females, 12 of which are heavy users and 12 were occasional users.[18] The study measured one's ability to operate a vehicle under Dronabinol, oral tetrahydrocannabinol (THC), and the findings were clear that the tolerance one has towards the drug is dose dependent because tolerances of heavy and occasional users varied. It was concluded that both groups' performance while driving was lowered upon 10mg and 20mg

[16] "Drowsy Driving And Automobile Crashes: NCSDR/NHTSA Expert Panel on Driver Fatigue and Sleepiness." PsycEXTRA Dataset
[17] COMMONWEALTH vs. THOMAS J. GERHARDT. 2017
[18] Bosker, W M, et al. "Medicinal Δ(9) -Tetrahydrocannabinol (Dronabinol) Impairs on-the-Road Driving Performance of Occasional and Heavy Cannabis Users but Is Not Detected in Standard Field Sobriety Tests." *Current Neurology and Neuroscience Reports.*, U.S. National Library of Medicine,

doses of Dronabinol. According to the SFST study, "dronabinol-induced increments in SDLP were bigger than impairment associated with BAC of 0.5 mg/ml in occasional and heavy users… driving impairment was generally less in heavy users", so there is evidence that at 20mg of Dronabinol you have in a similar performance of driving after a few drinks.[19] The standard field sobriety test, however, did not have the same results, with testing the subjects under Dronabinol, there was no sensitive driving impairment.

Cannabis vs Driving:

To date, cannabis is the most commonly used illicit drugs in the world[14] and recent studies suggest the rate of use is increasing. As the use rate of cannabis increases, the rate of people driving under the influence of cannabis will increase as well. One study performed by E. Wadsworth found around 30 percent out of the 4000 participants had consumed cannabis in the past. Out of those 30 percent of people, 28 percent had driven a car under the influence of cannabis before. People are commonly driving while under the influence of cannabis with little to no consequence. Furthermore, out of those 4000 people, about half of them believe driving under the influence of cannabis has little to no negative effect.[20] More advanced research on driving under the influence of cannabis is necessary to further regulate the new situation.

For new regulations for drivers driving under the influence to be introduced, cannabis research studies need to be performed in order to determine relevant symptoms of cannabis use that affect driving and motor skills. Recently, many studies regarding driving while under the influence of cannabis have highlighted skills that an individual needs in order to drive safely. The

[19] Sewell, R. Andrew, et al. "The Effect of Cannabis Compared with Alcohol on Driving." American Journal on Addiction
[20] Wadsworth, E. "International Differences in Patterns of Cannabis Use among Youth: Prevalence, Perceptions of Harm, and Driving under the Influence in Canada, England & United States." NeuroImage, Academic Press, 1 Nov. 2018,

studies show many different tasks that test each of these skills as well. Five primary driving skills and their respective task have been compiled and are outlined below:

Hand-Eye Coordination - Purdue Pegboard

The first skill that is essential to driving safely is hand-eye coordination. This skill is the ability to do activities simultaneously while using both hands and eyes. We use our eyes to direct attention to stimulus while we use our hands to carry out desired activities. Hand-eye is a complex cognitive ability that can be accurately tested using the Purdue Pegboard test. This test instructs the subject to place as many metal rods into slots on a pegboard with one hand as they can in a predetermined amount of time.[21]

Manual Dexterity - Grooved Pegboard

The second skill that will be involved in our testing is manual dexterity. This skill is the ability to use hands in a coordinated way to grasp or manipulate objects to demonstrate precise movements. While driving, we often get distracted and use our hands to do many other activities. Most of these activities involve small movements that need no-error outcomes in order for the activity not to distract our driving. An accurate way of testing one's manual dexterity is thru the Grooved Pegboard test. Subjects are asked to place differently shaped rods into a pegboard as quickly as they can.[22]

Motor Speed - Finger Tapping

The third skill being evaluated is motor speed. This skill is the ability to use any part of our body as quickly as possible. Generally, people immediately think motor speed involves running but motor speed can involve a lot more things such as how fast somebody throws or kicks

[21] Boggs, Douglas. "The Dose-Dependent Psychomotor Effects of Intravenous Delta-9-Tetrahydrocannabinol (Δ9-THC) in Humans." *Journal of Research in Crime and Delinquency*

[22] Croft, Rodney. "The Relative Contributions of Ecstasy and Cannabis to Cognitive Impairment." Original Investigation,

a ball. In our case, motor speed involved how quickly a subject can continuously react over a short period of time. While driving an individual's speed especially their hand speed are essential to driving safely. One way of testing this is thru the finger tapping test. The individual is instructed to press a button as many times as they can with one finger in a short period of time.[23]

Divided Attention - One Leg Stand Test

The fourth skill of importance is divided attention. Divided attention is the ability to attend to two different stimuli at the same time. While driving, an individual must brake and speed up while handling the wheel at a minimum. The individual will often perform a third or even a fourth activity while driving. Because of this, an individual's divided attention is very important. One simple way of testing divided attention is thru the one leg stand test. Subjects are asked to stand on one foot while raising the other and keeping their arms by their side.[24]

Visual Reaction Time - Go/No Go Test

The fifth and final skill involved in our testing is visual reaction time. This skill is the ability to efficiently, quickly, and actively react to stimuli. While driving anything can happen. Because of this, the driver needs to be able to react to sudden change as quickly as possible while still maintaining safety behind the wheel. One task that tests visual reaction time effectively is the go/no go test. Subjects are instructed to react to visual change on a screen as quickly and accurately as possible.[25]

[23] Roser, Patrik, et al. "Psychomotor Performance in Relation to Acute Oral Administration of Δ9-Tetrahydrocannabinol and Standardized Cannabis Extract in Healthy Human Subjects." SpringerLink, Springer
[24] Bosker, W. M., et al. "A Placebo-Controlled Study to Assess Standardized Field Sobriety Tests Performance during Alcohol and Cannabis Intoxication in Heavy Cannabis Users and Accuracy of Point of Collection Testing Devices for Detecting THC in Oral Fluid." SpringerLink, Springer
[25] McDonald, Jennifer, et al. "Effects of THC on Behavioral Measures of Impulsivity in Humans." Nature News, Nature Publishing Group

Methods:

In this section, the methods and procedures of the project are discussed. The design for the mechanical motor skills prototypes alongside the cognitive skill test will be outlined in further detail. The process of survey and questionnaire distribution to the study's participants and law enforcement are discussed as well.

Mechanical Prototyping Overview:

Before testing any subjects, two tasks used in our study needed to be physically created. In order to broaden our range of skills tested for each participant, two out of the five tasks will have a more hands-on approach instead of mainly focused on cognitive ability. Specifically, how both of the tasks were designed and created are detailed below:

Purdue Pegboard:

The Purdue pegboard tests the user's hand-eye coordination and motor control. The two lines of pins test how quickly a series of pins can be slotted into the holes and a washer placed on. The test can be repeated for individual hands or both hands at once. We will be constructing the test out of wood, pins, and washers.

Grooved Pegboard:

The pegboard is designed to test manual dexterity and visuospatial awareness. Using Solidworks, we created designs of a series of moveable blocks with hole shaped variations of a rectangle, oval, and triangle on top. The blocks are mounted on rails on the pinboard, and the pins only fit one way into the holes. This allows the time for puzzle completion to be timed and can be randomized after each turn. The pinboard and pins will be 3D printed, using ABS plastic. The pins are designed black to force the user to handle the pins to recognize which slot they belong in. See figure 19 and 20 for diagrams of both pegboards

Cognitive Skills Test:

Participants in our study will be instructed to complete five tasks. Every task is tailored specifically to a different skill commonly found in driving. More details of each skill and how they are related to driving

can be found in our Background Section "Cannabis vs Driving". Outlined below are descriptions of our five tasks. In each description, details on how the task is instructed to the participant and how each task is scored are discussed.

Purdue Pegboard Test:

The Pegboard test is used to determine the subject's hand-eye coordination. During the pegboard test, each subject will undergo three timed trials that will assess how much time it takes to place a designated number of pegs into a large wooden board with one hand. The first trial of the test is for your dominant hand, the second trial is for the non-dominant hand, and the third trial is for both hands simultaneously. The total amount of time plus the number of drops determine each subjects' final result score. Depending on how the subject performs compared to their sober baseline will determine each subject's results.

Grooved Pegboard Test:

The Pinboard test is used to determine the subject's manual dexterity. During the pinboard test, subjects will have to place 16 different shaped and sized pins (four by four matrix) into their respective hole as quickly and accurately as possible. The total amount of time plus the number of drops will determine each subject's final score. Depending on how the subject performs compared to their sober baseline will determine each subject's results.

Balance Test:

The Balance test is used to evaluate the subject's divided attention. During the test, the user is instructed to balance on one leg with the other leg raised and their arms tightly by their side. In order to pass the test, the subject will have to maintain balance for 15 seconds without falling, swaying, raising their arms, or hopping. Depending on how the subject performs compared to their sober baseline will determine each their results.

Finger Tapping Test:

The finger tapping test is used to determine the subject's motor speed. During the finger tapping test, the subject will undergo 5 trials of how quickly they can tap a screen within 20 seconds for each hand.

The average time of the five trials will determine the subject's final score. Depending on how quickly the user taps the screen compared to their sober baseline will help access their motor speed ability.

Go/No Go Test:

The Go/No-go test is used to measure visual reaction timing. During the test, each subject will undergo 3 different trials. For each trial, the user will memorize five different numbers. They will then be instructed to react to different numbers on a flashing screen. Each time one of the numbers they were supposed to memorize appears, the user is prompted to react. The average number of misclicks, reacting when it was an incorrect number, will determine the user's final score. Depending on how the subject performs compared to their sober baseline will determine each their results.

Questionnaires and Surveys:

Before each participant undergoes the testing, sober or impaired, they will be instructed to fill out the questionnaire in Appendix 3, 4, and 5. The questionnaire asks the participants basic introductory questions, cannabis usage, frequency questions, and judgment questions related to driving. To produce results that can be applied for law enforcement, an additional survey would be sent to police officers in both Fitchburg Massachusetts and Worcester Massachusetts to further understand the issue from two different departments.

Results:

Due to legal reasons regarding cannabis in the United States, the team could not perform testing on human subjects. Therefore, the team will be using a simulated data approach to carry out further analysis. A process on how the data was created in R language is outlined below:

Simulated Data:

Before creating any data, each of our tasks was paired with a recent cannabis study that utilizes the same task in their study. All data results were broken up into four cannabis dosage groups; Control, Low, Mid, and High. If the study did not utilize four different dosage levels, best judgment compared to the dosage levels that were present was used. For each task's results, the distribution and parameters of the

data was determined. For each dosage, the mean and standard deviation of the results were observed from the respective cannabis study. Once all of this determined, the simulated data was created using the appropriate distribution for each dosage on R. When all of the data was created, the team could perform their analysis (See Appendix 1).

Data Analysis:

Here we describe the analysis performed on our simulated data. First, boxplots for each of the tasks were created in order to visually summarize each of the results and an ANOVA analysis was performed to detect the differences among the four dosages. All calculations and analysis were performed in R language (See Appendix 1). Each of the tasks, their respective cannabis study, and our data analysis are outlined below:

Purdue Pegboard Test:

The data for this task was based on a study performed by Douglas Boggs from Yale University.[26] The results of the task in the study for both the non-dominated hand and the dominated hand can be seen in Table 1 and 2.

Table 1: Non-Dominating Hand Times

Non-Dominating Hand - Time	Control	Low	Mid	High
Mean	74	78	80	83
Standard Deviation	6	6	6	6

Table 2: Dominating Hand Times

Dominating Hand - Time	Control	Low	Mid	High
Mean	67	75	77	80

[26] Boggs, Douglas. "The Dose-Dependent Psychomotor Effects of Intravenous Delta-9-Tetrahydrocannabinol (Δ9-THC) in Humans." Journal of Research in Crime and Delinquency

Standard Deviation	6	6	6	6

Data was constructed using a normal distribution with each of the means and standard deviations for the dosage. The following boxplot visually summaries the results:

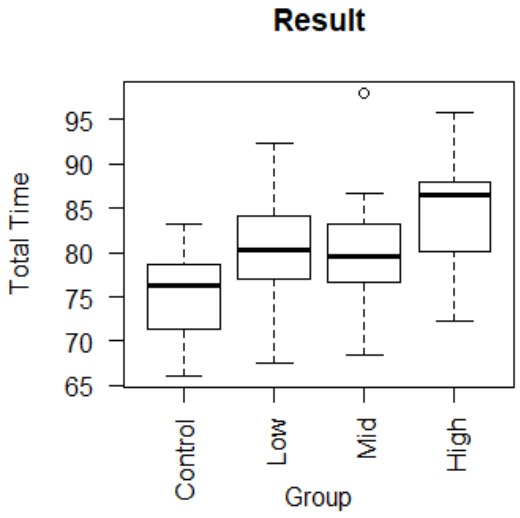

Figure 4: Results for Non-Dominating Hand Time

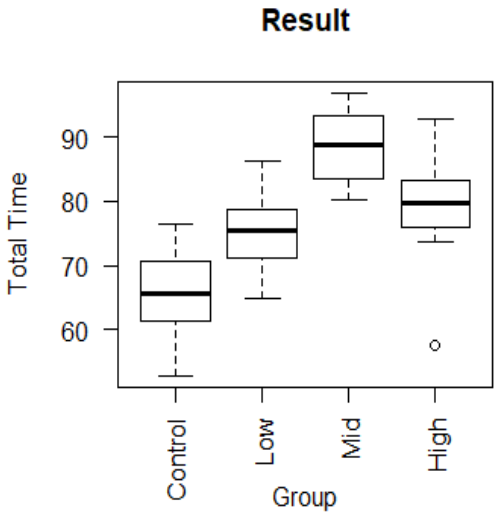

Figure 5: Results for Dominating Hand Times

After the boxplot was created, an ANOVA F-Test was performed to determine the significance between dosages. The analysis for the non-dominant hand resulted in a F value of 8.805 and a p value of 3.25*10^-5 which is smaller than 0.05. The analysis for the dominant hand resulted in F value of 57.11 and a p score of 2*10^-16 which is smaller than 0.05. Both ANOVA analyses resulted in a significant difference between dosages.

Grooved Pegboard Test:

The data for this task was based on results from a study performed by Rodney Croft's team.[27] The results of the task in the study for both the right hand and the left hand can be seen in Table 3 and 4.

Table 3: Grooved Pegboard Right-Hand Time

Right Hand - Time	Control	Low	Mid	High
Mean	56.5	61.5	65.5	68.5
Standard Deviation	6.6	7.1	7.7	8.1

Table 4: Grooved Pegboard Left-Hand Time

Left Hand - Time	Control	Low	Mid	High
Mean	63.4	64.5	66.6	68.5
Standard Deviation	8.5	8.2	7.9	7.6

Data was simulated using a normal distribution with each of the means and standard deviations for each dosage. The following boxplot visually summaries the results:

[27] Croft, Rodney. "The Relative Contributions of Ecstasy and Cannabis to Cognitive Impairment." Original Investigation

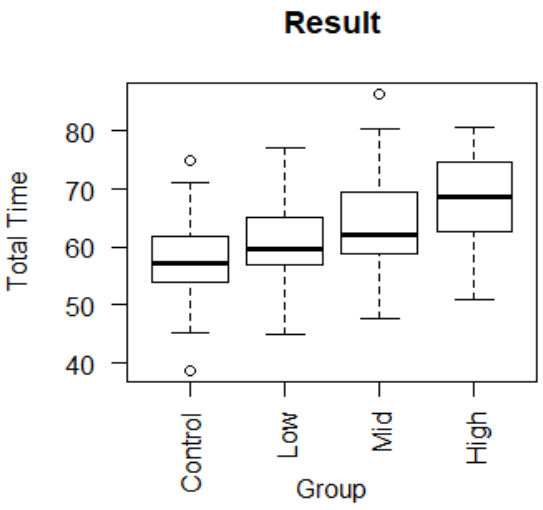

Figure 6: Grooved Pegboard Right-Hand Results

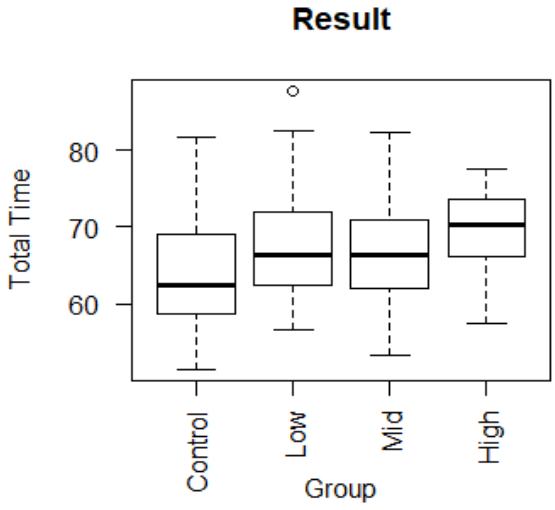

Figure 7: Grooved Pegboard Left-Hand Results

After the boxplots were created an ANOVA analysis was performed. The analysis for the right hand resulted in a F value of 7.064 and a p score of 0.000243 which is smaller than 0.05. The results for the left hand resulted in a F value of 1.034 and a p score of 0.381 which is greater than 0.05. The right hand resulted in a significant difference while the left-hand did not result in a significant difference.

Finger Tapping Test:

The random data was based on a study performed by Patrik Roser's for the European Psychiatry and Clinical Neuroscience.[28] The results of the task for both left and right hand can be seen in Table 5 and 6:

[28] Roser, Patrik, et al. "Psychomotor Performance in Relation to Acute Oral Administration of Δ9-Tetrahydrocannabinol and Standardized Cannabis Extract in Healthy Human Subjects." SpringerLink, Springer

Table 5: Finger Tapping Right Hand Time

Right Hand - Time	Control	Low	Mid	High
Mean	86.6	83.7	81.3	79.6
Standard Deviation	10.9	11.3	11.7	10.5

Table 6: Finger Tap Left Hand

Left Hand Time	Control	Low	Mid	High
Mean	74.7	72.2	71.5	70.1
Standard Deviation	9.6	11.6	12	12.5

Data was simulated using a normal distribution with each of the means and standard deviations for each dosage. The following boxplot visually summaries the results:

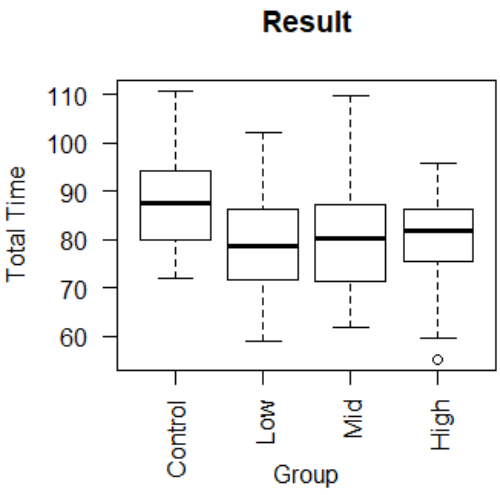

Figure 8: Finger Tap Right Hand Results

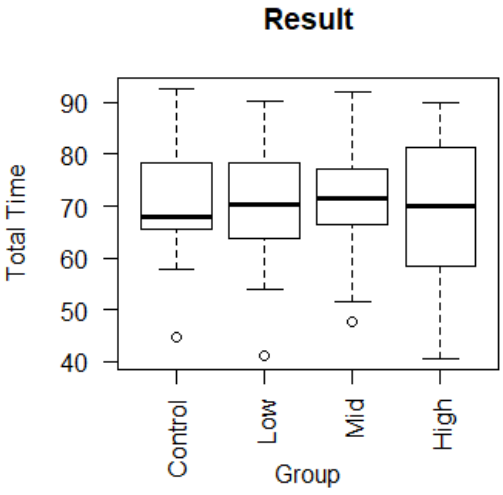

Figure 9: Finger Tap Left Hand Results

After boxplots were created an ANOVA analysis was performed. The right-hand analysis resulted in F value of 5.133 and a p score of 0.00246 which is smaller than 0.05. The left-hand

analysis resulted in F value of 0.213 and a p score of 0.887 which is not smaller than 0.05. Once again, the right hand resulted in a significant difference between dosages while the left hand did not.

One Leg Stand:

The random data was based on a study performed by W. Bosker and team[29]. The results of the task can be seen in Table 7:

Table 7: One Leg Stand Failure Rate

Failure Rate %	Control	Low	Mid	High
Mean	21%	50%	53%	56%

Data was simulated based on the study's failure rates. A box plot was not a useful visual to represent the data in table. Instead, only an ANOVA analysis was performed in order to determine a significant difference between dosages. The analysis resulted in F value of 6.299 and a p score of 0.000602 which is smaller than 0.05. This concludes that the one leg stand task has a significant difference between doses.

Go/No Go Test:

The random data was based on a study performed by Jennifer McDonald and team for Neuropsychopharmacology[30]. The results of the task can be seen in Table 8:

[29] Bosker, W. M., et al. "A Placebo-Controlled Study to Assess Standardized Field Sobriety Tests Performance during Alcohol and Cannabis Intoxication in Heavy Cannabis Users and Accuracy of Point of Collection Testing Devices for Detecting THC in Oral Fluid." *SpringerLink*

[30] McDonald, Jennifer, et al. "Effects of THC on Behavioral Measures of Impulsivity in Humans." *Nature News*, Nature Publishing Group

Table 8: Go/No-Go Test Table

# of Misclicks	Control	Low	Mid	High
Mean	7.5	7.6	7.8	8.1
Standard Deviation	2	2	2.4	2.8

Data was simulated using a normal distribution with each of the means and standard deviations for each dosage. The following boxplot visually summaries the results:

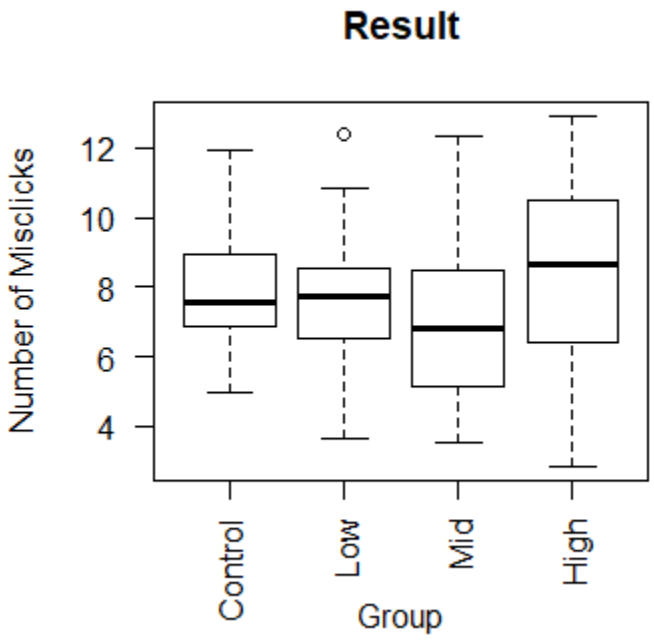

Figure 10: Go/No-Go Test Results

After the boxplot was created an ANOVA analysis was performed to determine significance. The analysis resulted in a F value of 3.609 and a p score of 0.00134 which is smaller than 0.05. This concludes that the one leg stand test has a significant difference between doses.

Mechanical Prototype Development:

The board development was a multistep process. Both boards were designed simultaneously, to achieve similar tasks. The Purdue pegboard design is essentially identical to the previously created pegboard, however the pegs continue in a swept pattern outwards from the center towards the bottom.

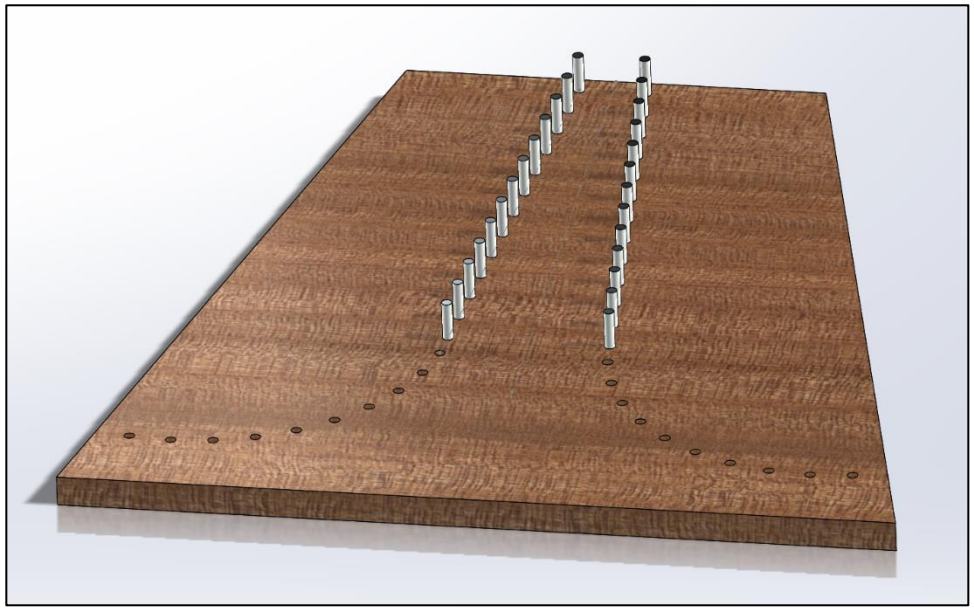

Figure 11: Purdue Pegboard

This change was implemented after primary design, because coordination in the peripheral areas of vision is extremely important. As far as construction, the Purdue pegboard is made from plywood, with steel pins. The intended use of the board is to test individual hand-eye coordination, then both sides at the same time. Any form of inebriation will make the test more challenging, especially testing both sides of the body at once.

The Grooved pegboard is designed to test visuospatial awareness. The original design was a solid board with circular holes that had one keyed slot. The identical pins would fit only one way in the keyed slot. The initial modification was to change the holes to three different shapes;

circular, rectangular, and triangular. We also added a track system, so the hole pattern of the board can be randomized.

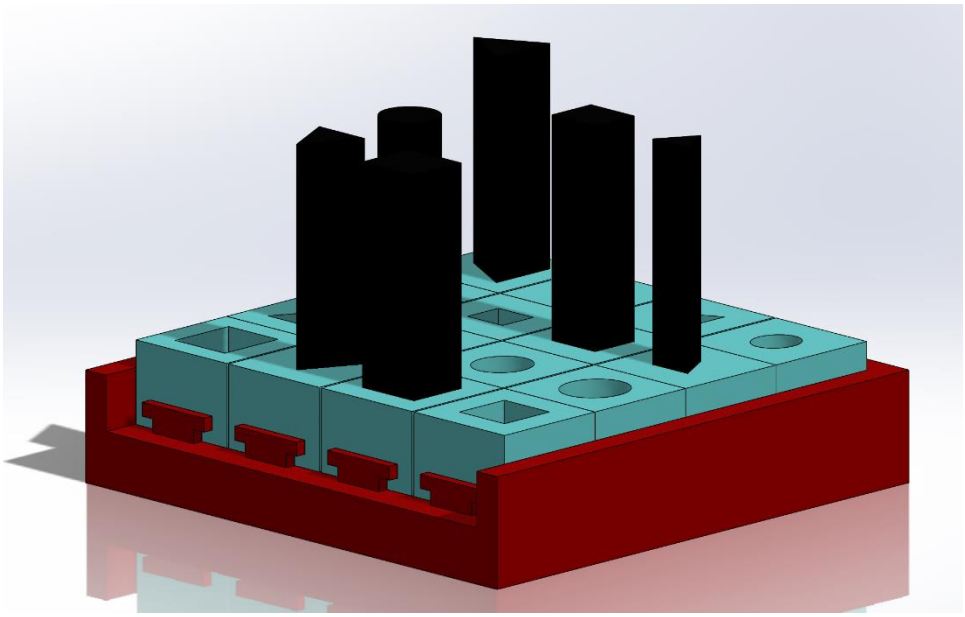

Figure 12: Grooved Pegboard

The final design features shaped slots that can only accept a single specific shaped pin, and that can be randomized for every test. The board, pin slots, and pins were all 3D printed out of ABS plastic, ensuring that all components fit together well and slide easily. The purpose of this test is to test whether the subject can accurately tell what pin fits where, based on shape and feel. Timing the test and randomizing it after each use will allow the test administrator to tell if the subject is under the influence of anything.

Conclusion/Discussion/Recommendations:

Through our analysis, we can conclude that cannabis influence does have a negative effect on certain driving skills. Based on our results, hand-eye coordination, divided attention, and visual reaction skills were affected the most by cannabis influence. Both the subject's manual dexterity and motor speed had negative effects as well but only on the right hand. This observation could be a result of the majority of study participants were right handed. Therefore, when trying to show negative effects on their left hand, their control results were much worse than their right hand. Further research and experimentation is needed to confirm our results and conclusions in order for new laws to be set in place to prevent cannabis users from driving under the influence while driving and keep our roads and highways safe.

Law and Ethics behind cannabis impairment and LEOs:

Tests for potential DUI drivers under the influence of cannabis have been around for many years. Police officers are trained to conduct one of three tests, depending which they have been trained for, and the circumstances. The tests that can be conducted include: Standard Field Sobriety Test (SFST), Advanced Roadside Impaired Driving Enforcement (ARIDE), and Drug Recognition Expert (DRE) Training Program.

The SFST is most commonly known to be administered to those under the influence of alcohol, which has three tests; it tests one's ability to follow an object (usually a pen or flashlight) with their eyes without moving their head, known as Horizontal Gaze Nystagmus Test, followed by the Walk and Turn test which measures balance and coordination, then a one-legged stand test, which tests balance as well as ability to follow directions and maintain focus.

These tests measure practical parameters for drivers, however there is sufficient arguments that are against this tests validity for cannabis users, because any details moving away from

National Highway Traffic Safety Administration (NHSTA) guidelines can be dismissed in court due to the fact tests could be invalid. The ARIDE training was developed by the NHSTA and International Association of Chiefs of Police (IACP) for the purposes to bring together the gap between SFST and DRE. This test was aimed to get DUI operators off the road or to further the process to a full DRE test conducted usually back at the police station. The training for ARIDE is 16 hours long and helps LEOs to help identify drivers who are under the influence of any drug.

Finally, the DRE training program was developed to detect impaired drivers, reduce automobile accidents, and avoid deaths. This program is offered in all 50 states, and LEOs that complete the training become Drug Recognition Experts. The DRE program is 72 hours of classroom training, a field certification, and a comprehensive final exam. DREs maintain their certification by participating in training, recertification every two years, and to keep a log of every evaluation conducted; along with any state specific requirements. See appendix 2 for the 12 step DRE test.

The benefits and limitations for these tests are intuitive to explain that some drivers are more inclined to fail tests without being under the influence of any drug but rather a preexisting health condition. For example, some people have a hard time focusing their eyes due to eye conditions unrelated to drug use. Likewise, the one-legged stand is not easily taken for some that may be obese or have bad leg pain, again unrelated to drug use. Therefore, these tests are not equally designed for everybody and certain ramifications should be taken, or a new test should be developed for those with preexisting health conditions limiting their participation and skewing their chances of failing.

The results propose an issue regarding driving safety with the influx of cannabis users in the United States. In order to maintain safety, new legislation and regulations need to be created

and enforced to suppress the situation and maximize the number one concern which is driving safety. With this report, we want to assist in the further development of cannabis research and the effect the drug has on driving ability. Additional ramifications have been taking place in our own state, Massachusetts. The Cannabis Control Commission of Massachusetts recently rolled out a baseline review about driving safety and proposes to have new legislation put into place within the next few months after sufficient data has been analyzed to make the best decision for a legal driving limit. With this brand-new program coming out there is a positive outlook on cannabis driving safety for the public and a foundation for LEOs to make comprehensive judgments when doing their job.

Appendices:

Appendix 1: Data Creation

At first the data needed to be created using random functions:
Data Creation:
PPNDH = data.frame(Control = rnorm(25,mean=74,sd=6), Low = rnorm(25,mean=78,sd=6), Mid = rnorm(25,mean=80,sd=6), High = rnorm(25,mean=83,sd=6))
PPDH = data.frame(Control = rnorm(25,mean=67,sd=6), Low = rnorm(25,mean=75,sd=6), Mid = rnorm(25,mean=87,sd=6), High = rnorm(25,mean=80,sd=6))
GPRH = data.frame(Control = rnorm(25,mean=56.5,sd=6.6), Low = rnorm(25,mean=61.5,sd=7.1), Mid = rnorm(25,mean=65.5,sd=7.7), High = rnorm(25,mean=68.5,sd=8.1))
GPLH = data.frame(Control = rnorm(25,mean=63.4,sd=8.5), Low = rnorm(25,mean=64.5,sd=8.2), Mid = rnorm(25,mean=66.6,sd=7.9), High = rnorm(25,mean=68.5,sd=7.6))
FTRH = data.frame(Control = rnorm(25,mean=86.6,sd=10.9), Low = rnorm(25,mean=83.8,sd=11.25), Mid = rnorm(25,mean=81.3,sd=11.7), High = rnorm(25,mean=79.58,sd=10.5))
FTLH = data.frame(Control = rnorm(25,mean=74.7,sd=9.6), Low = rnorm(25,mean=72.1,sd=11.6), Mid = rnorm(25,mean=71.5,sd=12), High = rnorm(25,mean=70.1,sd=12.5))
OLS = data.frame(Control = rbinom(25,1,.21), Low = rbinom(25,1,.5), Mid = rbinom(25,1,.53), High = rbinom(25,1,.56))
GNG = data.frame(Control = rnorm(25,mean=7.5,sd=2), Low = rnorm(25,mean=7.6,sd=2), Mid = rnorm(25,mean=7.8,sd=2.4), High = rnorm(25,mean=8.1,sd=2.8))

A list of the data fields names are below. You can see the full data set by typing in each of these names in R.
PPNDH
PPDH
GPRH
GPLH
FTRH
FTLH
OLS
GNG

Code for how the Boxplots were created:
boxplot(PPNDH,las=2,ylab="Total Time",xlab="Group",main="Result")
boxplot(PPDH,las=2,ylab="Total Time",xlab="Group",main="Result")
boxplot(GPLH,las=2,ylab="Total Time",xlab="Group",main="Result")
boxplot(FTRH,las=2,ylab="Total Time",xlab="Group",main="Result")
boxplot(FTLH,las=2,ylab="Total Time",xlab="Group",main="Result")
boxplot(GNG,las=2,ylab="Number of Misclicks",xlab="Group",main="Result")

In order to the ANOVA analysis the data needed to be stack. That code for each test is below:
Stack_PPNDH = stack(PPNDH)

```
Stack_PPDH = stack(PPDH)
Stack_GPRH = stack(GPRH)
Stack_GPLH = stack(GPLH)
Stack_FTRH = stack(FTRH)
Stack_FTLH = stack(FTLH)
Stack_OLS = stack(OLS)
Stack_GNG = stack(GNG)
```

These field names check to see the data was stacked and see the entire stacked results.

```
Stack_PPNDH
Stack_PPDH
Stack_GPRH
Stack_GPLH
Stack_FTRH
Stack_FTLH
Stack_OLS
Stack_GNG
```

Code for the Anova analysis:

```
PPNDH_ANOVA = aov(values~ind, data= Stack_PPNDH)
PPDH_ANOVA = aov(values~ind, data= Stack_PPDH)
GPRH_ANOVA = aov(values~ind, data= Stack_GPRH)
GPLH_ANOVA = aov(values~ind, data= Stack_GPLH)
FTRH_ANOVA = aov(values~ind, data= Stack_FTRH)
FTLH_ANOVA = aov(values~ind, data= Stack_FTLH)
OLS_ANOVA = aov(values~ind, data= Stack_OLS)
GNG_ANOVA = aov(values~ind, data= Stack_GNG)
```

Code for the Anova Summary:

```
summary(PPNDH_ANOVA)
summary(PPDH_ANOVA)
summary(GPRH_ANOVA)
summary(GPLH_ANOVA)
summary(FTRH_ANOVA)
summary(FTLH_ANOVA)
summary(OLS_ANOVA)
summary(GNG_ANOVA)        `
```

Appendix 2: DRE Test

The DRE test includes 12-steps:

1. Breath Alcohol Test
2. Interview by Conducting Officer
    a. DRE reviews the reasoning for arresting and asks the driver questions about behavior, driving, and appearance.
3. Preliminary Exam and First Pulse
    a. DRE asks a series of questions related to driver's health and recent consumption. The DRE also conducts SFST such as horizontal gaze nystagmus. A DRE can also measure pulse, speech, breath, pupils, and facial expression.
4. Eye Examination
    a. The DRE will conduct a series of tests including horizontal gaze nystagmus (HGN), vertical gaze nystagmus (VGN), and a lack of convergence (inability to cross eyes) to record in their DRE log.
5. Divided Attention Psychopathically
    a. The DRE administers four psychophysical tests, The Modified Romberg Balance, Walk and Turn, One Leg Stand, and Finger to Nose test, each is recorded by DRE.
6. Vital Signs and Pulse
    a. The DRE measures blood pressure, pulse, and temperature.
7. Dark Room Examination
    a. During the Dark Room test, the DRE measures the pupils of the subject in three different lighting scenarios using a pupilometer to determine if pupils are normal or not.
8. Examination of Muscle Tone
    a. Some drugs make muscles to become rigid, the DRE exams for these signs.
9. Visual Check for Injection Sites and Third Pulse
    a. The subject is examined for injection sites and a third and final pulse is taken.
10. Subject's Statements and Other Observations
    a. If not done already, your Miranda Rights are read and a series of drug-use questions are asked.
11. Analysis and Opinions of the Evaluator
    a. The DRE makes an objective opinion based on the previous tests whether the driver was impaired to drive and indicates what category of drugs contributed.
12. Toxicology Examination
    a. In Massachusetts urine is taken and tested to see what substance(s) are present.

Appendix 3: Pre-Experiment Questionnaire

We just wanted to start off and say thank you for taking our test. Your assistance will help our team immensely in our project. This questionnaire is 100% voluntary and anonymous unless one of our team members reaches out to you personally and asks to use your personal information. You do not have to answer any of the questions you do not feel comfortable, but the team appreciates your honesty and openness with our questions. Feel free to ask the team member that handed you the questionnaire any questions you have as you are filling it out.

Questionnaire (Before Testing, The Day of Experiment):

Name: Age: Email:

When was the last time you've consumed cannabis?

How did you consume the cannabis?

In the past, have you driven impaired by cannabis?

If yes, how regularly would you say you drive while impaired by cannabis?

Would you feel safe driving a vehicle right now?

Additional Comments:

Appendix 4: Post Experiment, Feedback Questionnaire

We hope you enjoyed our test and we would once again like to thank you for your assistance. Before you leave, we would like to ask you to fill out a short feedback questionnaire. Feel free to be as honest and thorough as you'd like. As always, everything you say on these questionnaires are anonymous unless asked for permission otherwise.

Name: Age: Email:

Did you enjoy the testing process?

In your opinion, can you see this test used for law enforcement (Preventing those from driving under the influence):

What limitations does our test have for testing ability to drive?

Additional Comments:

Appendix 5: Questionnaire for Test Subjects Recruitment

Thank you for volunteering to be part of our experiment. As you may probably know, cannabis has increasingly been gaining support and new consumers the past few years. With recreational dispensaries open in Massachusetts we must consider the risks of operating vehicles under the influence of cannabis. With your help, we hope to help establish a baseline study to help lawmakers establish a legal limit of consumption as well as a good sobriety test to assist officers in determining whether someone is capable of driving safely. Furthermore, this survey is anonymous, and will not be published without permission.

1. How often do you consume cannabis?
   A. More than once a day
   B. More than once a week
   C. More than once a month
   D. Once a month
   E. Less than once a month
   F. Once a year
   G. I have never consumed cannabis

2. What type of consumer would you consider yourself?
   A. Heavy consumer
   B. Intermediate consumer
   C. Light consumer
   D. None

3. How high of a tolerance to cannabis would you consider yourself?
   A. Very high
   B. High
   C. Intermediate
   D. Low
   E. Extremely low
   F. No tolerance

4. What is your regular consumption method? (circle as many as apply)
   A. Combustion (smoking from pipe, joint, blunt, bowl, bong, etc.)
   B. Edible (candy, butter, brownies, cookies, etc.)
   C. Vaporizer
   D. Concentrates (Dab pen, dab rig, etc.)
   E. Droplets (tincture typically administered under the tongue)
   F. I do not consume cannabis

5. Would you consider driving after consuming cannabis?
   A. Yes
   B. No
   C. Depends how much I've had

D. I plan to have a sober driver

6. Do you have a limit for yourself that would keep you from driving? If so, please explain.
_____
_____
_____
_____

7. Have you been pulled over by a police officer before? (If no, ignore question 8 and 9)
A. Yes
B. No

8. Did you get a citation from this confrontation?
A. Yes
B. No
C. Prefer not to say

9. If you are pulled over having done nothing wrong, psychologically, are you intimidated to the point as if you did something wrong?
A. Yes
B. No
C. I do not know

10. When you are under the consumption of cannabis, what is your typical experience? (Choose as many that apply)
A. Happy
B. Stressed
C. Relieved
D. Sad
E. Energetic
F. Tired
G. All of the above
H. None

11. If you still are interested in participating with our experiment please leave us your contact info below for follow-ups and our experiment schedule, thank you!

Appendix 6: Law Enforcement Questionnaire

First off, we would like to thank each and every one of you for participating in our study. Your sacrifice to work in a dangerous environment in the line of duty is a noble decision and we appreciate your service. With cannabis being legal now, our team at WPI is trying to produce a relatively new concept to decipher impairment in drivers. With that being said, through research it was found that the typical Standard Field Sobriety Test, while a good measure for drunk

drivers, could be improved for those under the influence of cannabis (mainly in intermediate to heavy users). So, we are in the process of generating a series of tests that measure cognitive ability to focus, maintain focus, have proper hand-eye-coordination, and visual reaction tests. With your input, we can fine tune our design for more practical use or move in a different direction. Any and all of your comments are appreciated. Further, this survey is anonymous, and will not be published without permission.

1. How long have you been a law enforcement officer?
2. How has cannabis been handled up until legalization, and now after legalization?
3. Do you stop vehicles under the suspicion of cannabis use?
4. How often do you stop vehicles with drivers under the influence of cannabis?
5. Would law enforcement consider an app (for iPhone, Droid, etc.) that helps determine someone's cognitive capability for driving? (answer to your best knowledge, there are no wrong answers)
6. What types of tests would you imagine seeing on this app?
7. If not an application, would a physical test made with the same parameters be considered? (answer to your best knowledge, there are no wrong answers)
8. Rate importance of this subject (cannabis-Impaired driving)
9. Additional Comments:

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